



Toward real-time embedded observer of unsteady fluid flow environment

Valentin Resseguier, Matheus Ladvig, Agustin M Picard, Etienne Mémin,
Bertrand Chapron

► To cite this version:

Valentin Resseguier, Matheus Ladvig, Agustin M Picard, Etienne Mémin, Bertrand Chapron. Toward real-time embedded observer of unsteady fluid flow environment. ERTS 2020 - 10th European Congress Embedded Real Time Systems, Jan 2020, Toulouse, France. hal-02465508

HAL Id: hal-02465508

<https://inria.hal.science/hal-02465508>

Submitted on 3 Feb 2020

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

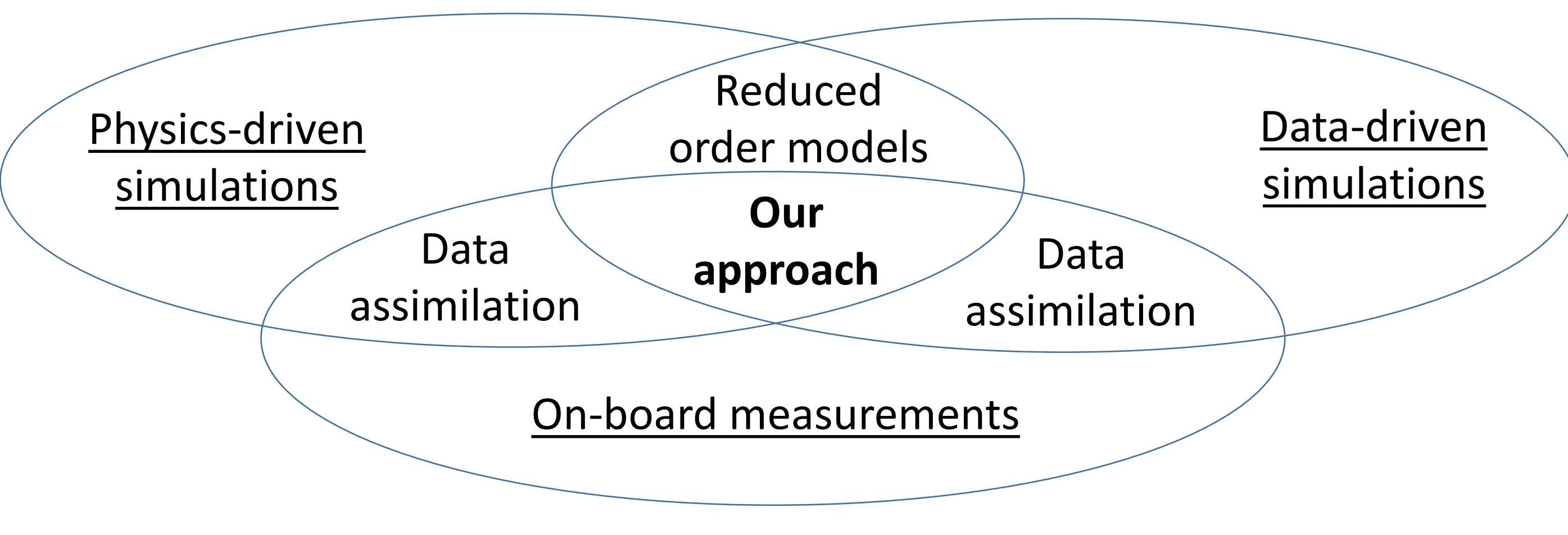
Toward real-time embedded observer of unsteady fluid flow environment

V. Resseguier, M. Ladvig, A. M. Picard, E. Mémin and B. Chapron



ABSTRACT

For monitoring and actively controlling hydrodynamic and aerodynamic systems (e.g. aircraft wing), it can be necessary to estimate in real-time and predict the flow around those systems. We propose here a new method which combines data, physical models and measurements for this purpose. Very good numerical results have been obtained on 2- and 3-dimensional wake flows at moderate Reynolds, even 16 vortices shedding cycles after the learning window.



APPLICATIONS

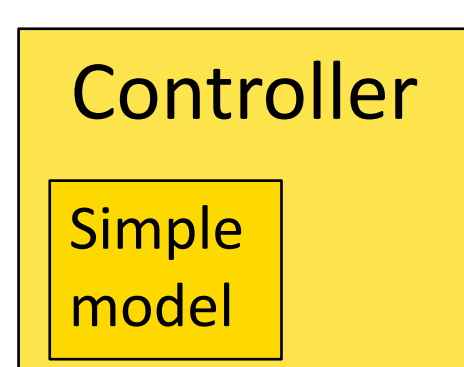
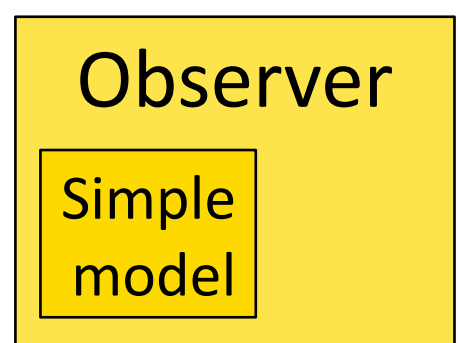


Robust and ultra-fast aerodynamic and aeroelastic short-time prediction for better active control loops.

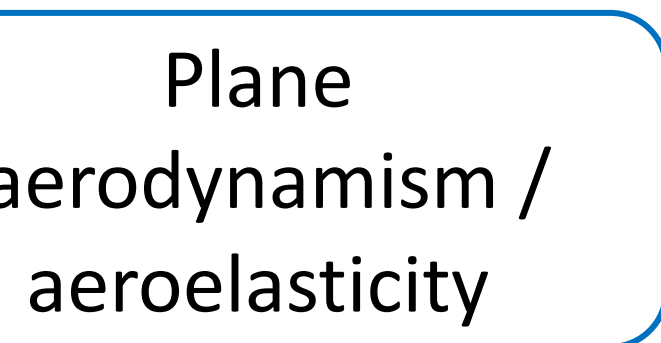
- active flutter suppression
- Drag reduction
- Passengers comfort
- Fuel economy

Estimation and prediction:

- Flow
- Lift, drag
- ...



- Flaps, slats
- Fluidic actuators
- ...

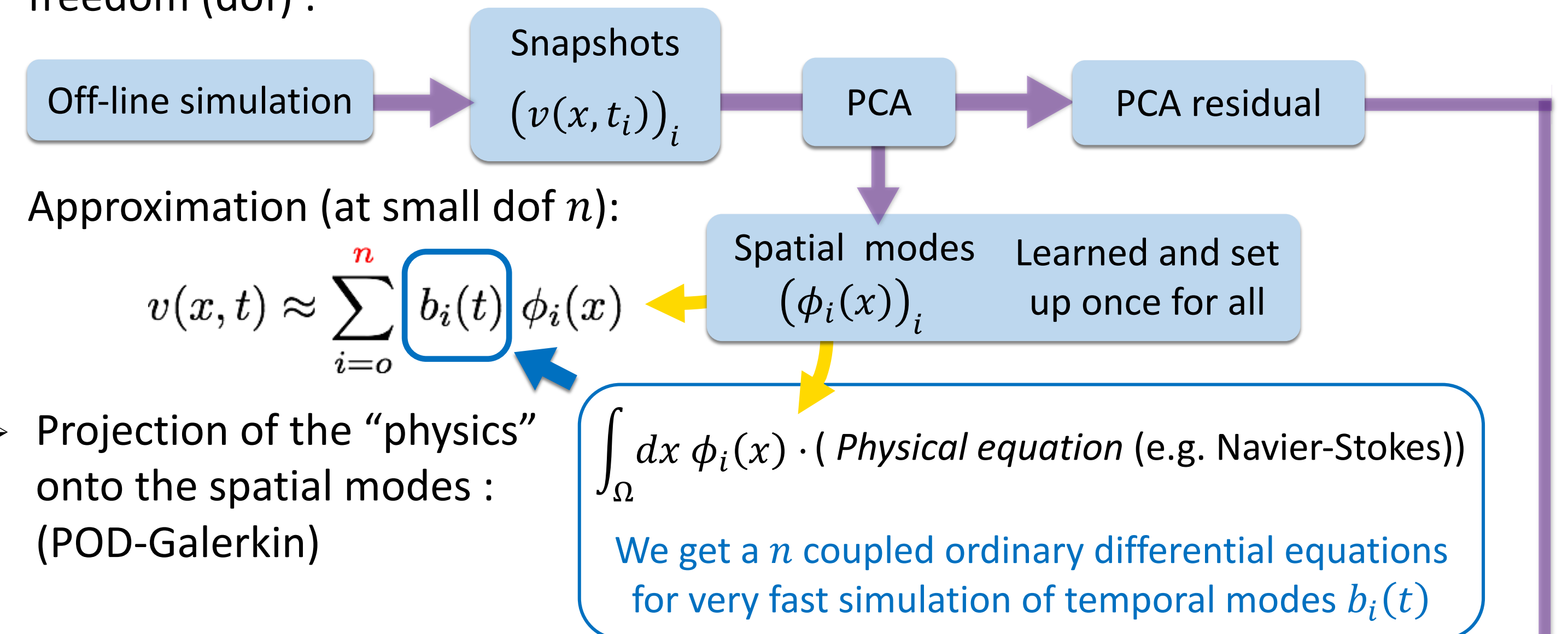


Which simple model? How to combine model & measurements?

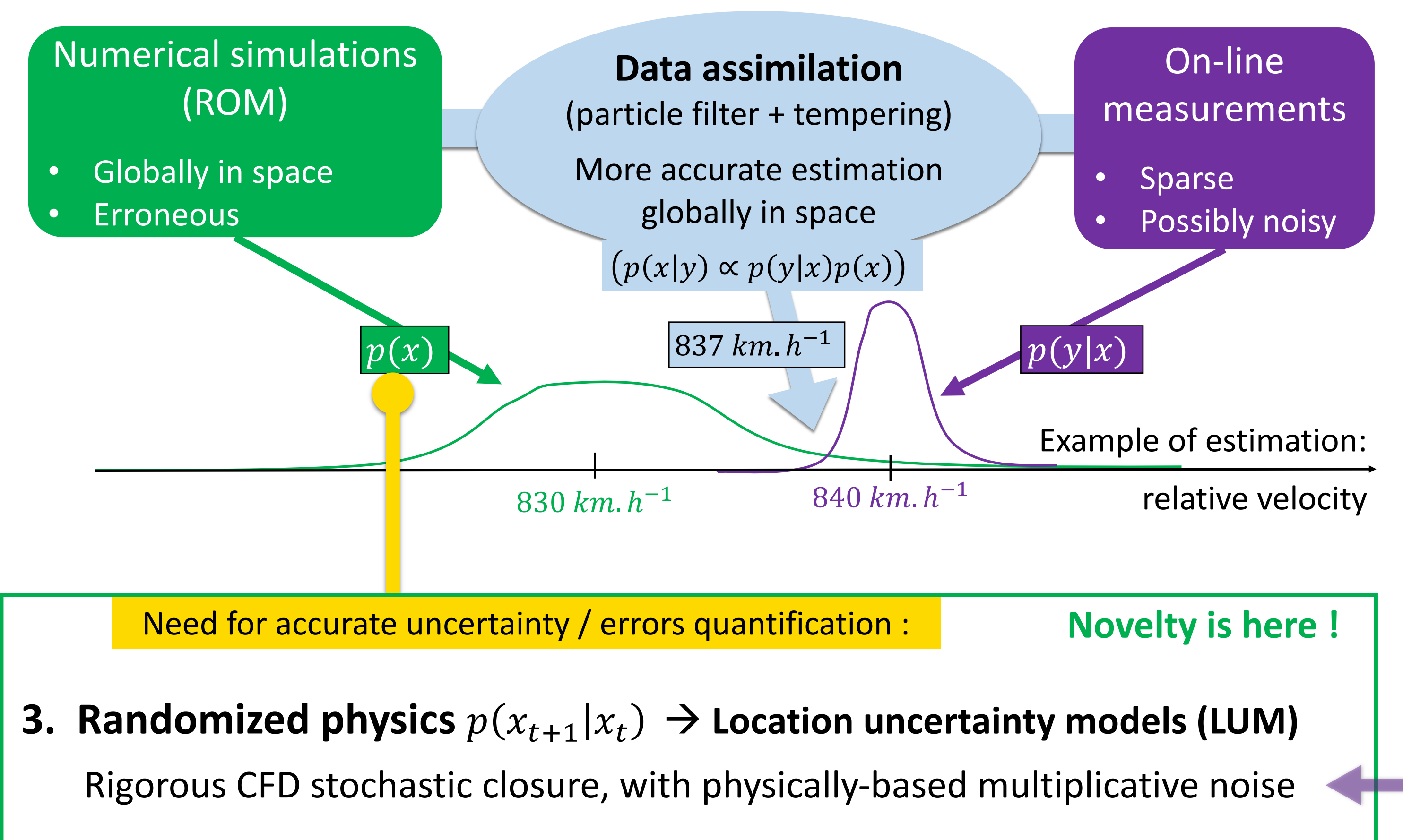
METHODOLOGY

1. Ultra-fast CFD simulations with intrusive reduced order models (ROM)

- Principal Component Analysis (PCA) on a *dataset* to reduce the degrees of freedom (dof) :



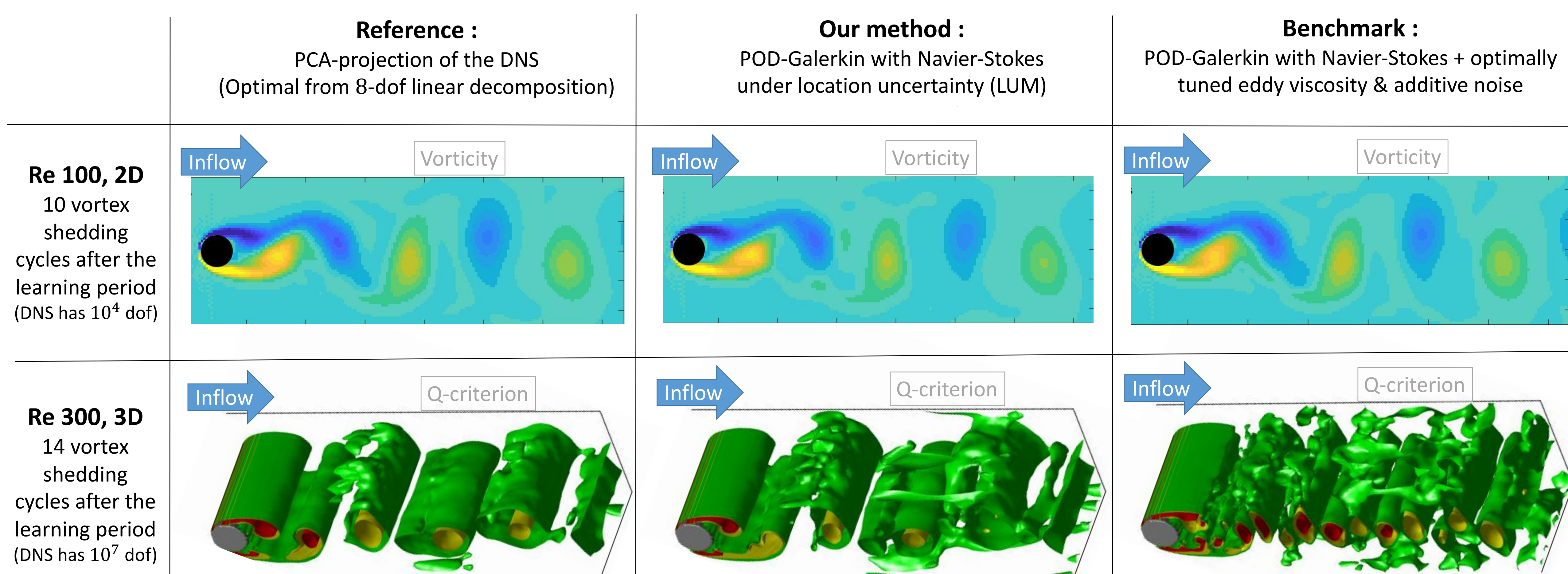
2. Measurement-simulation coupling (data assimilation)



3. Randomized physics $p(x_{t+1}|x_t) \rightarrow$ Location uncertainty models (LUM)

Rigorous CFD stochastic closure, with physically-based multiplicative noise

NUMERICAL RESULTS FOR $n = 8$ DEGREES OF FREEDOM (DOF) (ORDER OF THE ROM)



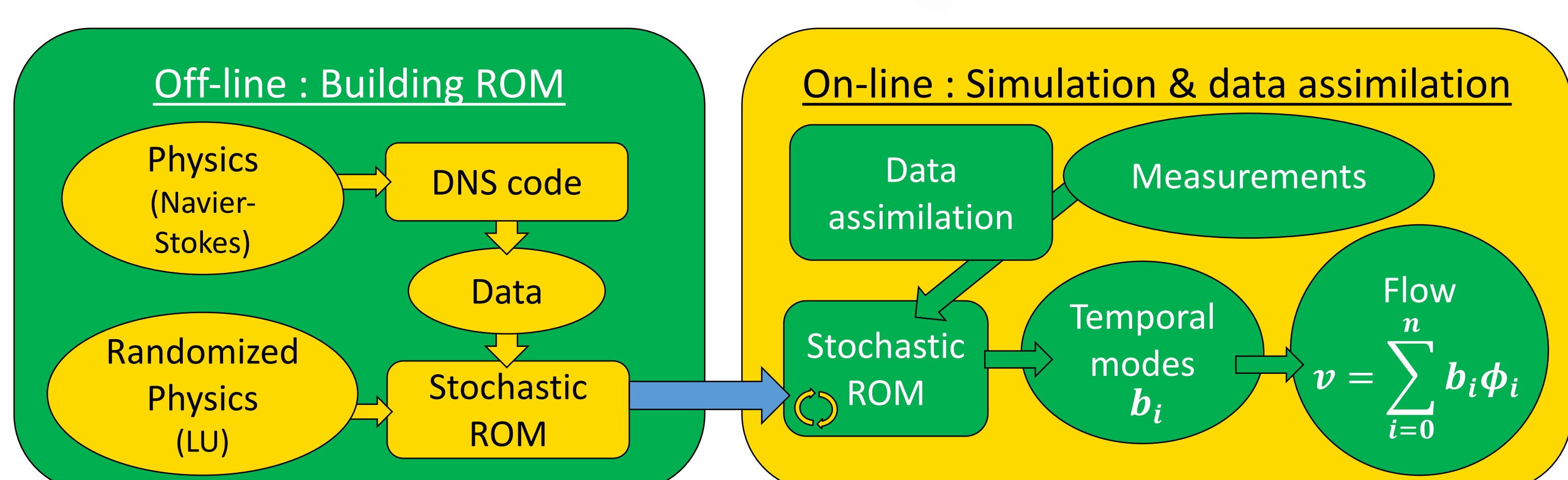
Tests description

- Same data assimilation algorithms
- Observation is one spatial resolution points of synthetic 2D PIV measurements, assimilated ten times by vortex shedding cycles.

CPU

- **Generate the simulation dataset** : several hours on a supercomputer (high-resolution CFD).
- **ROM construction** : several hours on a laptop (non-parallelized MATLAB® code).
- **On-line data assimilation** : approximately real time on a laptop (non-parallelized Python™ code).

METHODOLOGY SUMMARY



CONCLUSION

- Reduced order model (ROM) : for very fast and robust CFD
- Combine data & physics (built off-line) // Closure problem handled by LUM
- Data assimilation : to correct the fast simulation on-line by incomplete/noisy measurements // Model error quantification handled by LUM
- Robust prediction far outside the learning period
- Optimal unsteady flow estimation/prediction in the whole spatial domain

NEXT STEPS

- Real measurements
- Increasing complexity (dof, Reynolds, geometry, ...) ➤ Control loop